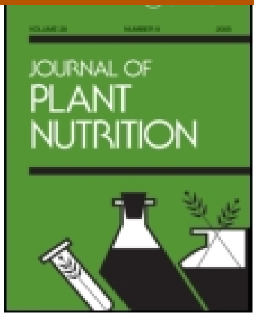

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Effect of nutrient solution salinity and ionic concentration on parsley (*Petroselinum crispum* Mill.) essential oil yield and content

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ABSTRACT

The growth and essential oil (EO) production of parsley were evaluated in response to salinity and nutrient solution concentrations in a soilless culture. Parsley plants that were 60 days old were potted in a coconut fiber and peat moss medium and were treated with four different nutrient solutions, including T1, T2, T3 and T4. The T1 nutrient solution was the standard, the T2 and T3 solutions contained incremental macronutrient concentrations with an electrical conductivity (EC) of up to 2.2 and 3.2 dS m^{-1}, respectively, and the T4 solution was the same as T2 but with sodium chloride (NaCl) and an incremental macronutrient concentration with an EC of 3.2 dS m^{-1}. Next, these plants were grown for 90 days in a greenhouse with natural daylight in Nador, Morocco. Shoot and root growth significant decreased with increasing EC. However, the salinity that resulted from the addition of NaCl did not affect plant growth in the nutrient solutions. The optimum obtained growth and EO production were 1.2 and 2.2 dS m^{-1}, respectively. Consequently, the optimum EC value (based on the EO production) of parsley in the soilless culture was 1.2–2.2 dS m^{-1}.

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Salinity; saline stress; medicinal and aromatic plants; growth and development; salt tolerance; soilless culture; coconut fiber; specific salinity effect

Introduction

Parsley, *Petroselinum crispum* Mill. (Umbelliferae), is a biennial plant that is widely used to garnish and aromatize foods (as fresh green sprigs) and as a medicinal and aromatic plant. Parsley is grown throughout most of the world.

Since the middle ages, essential oils have been widely used for bactericidal, virucidal, fungicidal, antiparasitic, insecticidal, medicinal and cosmetic applications, especially in the pharmaceutical, sanitary, cosmetic, agricultural, and food industries (Bakkali et al., 2008). Regarding crop protection, plant essential oils have been recently used against specific pests and fungi (Daferera et al., 2003; Isman, 2003). Parsley (*Petroselinum crispum* Mill) contains flavonoids (apiin and luteolin) and essential oils (apiol and myristicin) that are responsible for the medical uses and toxicity of parsley. Furanocoumarins (psoralen, bergapten, isoimperatorin, oxypeucedanin, xanthoxin, trioxsalen and angelicin) are also an important chemical component of parsley plants (Mimica-Dukiae and Popoviae, 2007). Furthermore, myristicin (63.9%) and apiol (14.4%) are major constituents of parsley. However, 34 additional essential oil compounds have been found in parsley (Pino et al., 1997).

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Since the 1960s, the influence of salinity on horticulture (Sonneveld and Voogt, 2009) and aromatic plants (Sonneveld et al., 1999) has been studied.

The scarce availability of water in the Mediterranean basin is one of the main factors that will limit agricultural development, particularly between 2000 and 2025 (Chartzoulakis et al., 2002). To overcome water shortages and to satisfy the increasing water demands of agricultural development, the use of marginal quality water (brackish, reclaimed, and drainage) will become necessary in many countries (Correia, 1999; Hamdi et al., 1995). However, the use of saline water for irrigation requires an adequate understanding of how salts affect plant performance.

The increasing demand for irrigation water is a worldwide problem. Additionally, poor quality water is a resource that has not been fully exploited, especially in semi-arid zones. In semi-arid zones where water quality is poor, the efficiency of nutrient use must be enhanced by adjusting the ion concentrations of the nutrient solutions. This task must be performed without decreasing production and by avoiding contaminant emissions as much as possible (Urrestarazu et al., 2008).

Many commercial greenhouse industries are forced to use poor quality water due to the presence of sodium chloride (NaCl). Occasionally, low to moderate levels of salinity are achieved in soilless culture by adding NaCl or major nutrients to improve fruit quality (Adams, 1991). This cultural management method could potentially be applied to essential oil production.

Contrasting reports are present in the literature regarding the response of essential oils to salt stress (15). For example, low and moderate saline stress has been shown to affect fennel (Abd El-Wahab, 2006) and marjoram (Baatour et al., 2010) negatively. In contrast, other authors recorded lower EO production when aromatic and medicinal plants were subjected to stress. For example, Baher et al. (2002) reported that the essential oil (EO) production of *Satureja hortensis* plants decreased when they were subjected to water stress. Similar results were obtained for *Lipia citriodora* under salt stress (Tabatabaie and Nazari, 2007). In contrast, the same authors reported that EO production in *Menhta piperita* did not decrease under the same saline conditions.

Therefore, the beneficial or detrimental effects of salt stress or nutrient solutions that are enriched with NaCl are different dependent on the type of plant tested.

In contrast, the advantages of soilless culture for growing medicinal plants suggest that these cultivation systems could be a powerful tool for the medicinal product industry (Hyden, 2006).

Very few studies have focused on the effects of nutrient solutions on soilless aromatic or medicinal plant crop from the following perspectives: 1) growth [e.g., Urrestarazu et al. (2013) using thyme lime], 2) biomass and essential oil production [e.g., Maia et al., (1999) using garden mint; Cordovilla et al. (2013) using thyme and lavender] or 3) essential oil production (based on biomass) and the ratio or concentration of each essential oil in peppermint and lemon verbena plants] (Tabatabaie and Nazari, 2007) (Table 1).

The objective of this experiment was to determine the effects of a nutrient solution's electrical conductivity (EC) and salinity (NaCl) on the growth and essential oil production of parsley.

Table 1. Examples of nutrient solution manipulation experiments in aromatic and medicinal crops grown in soilless culture.

Plant	Reference	Biomass yield	Essential oil (EO) production	Component (EO)	Remark
Lipia citriodora var. Verbena	Tabatabaie and Nazari (2007)	Yes	Yes	Yes	Level of EC and NaCl
Mentha crispa	Maia et al. (1999)	Yes	Si	No	Fertigation Method
Mentha piperita var. officinalis	Tabatabaie and Nazari (2007)	Yes	Yes	Yes	Level of EC and NaCl
Petroselinum crispum	Chondraki et al. (2012)	Yes	No	No	Level of EC by NaCl under NFT
Satureja hortensis	Najafi et al. (2010)	Yes	Yes	Yes	Level of EC and NaCl. Water culture
Thymus citriodorus	Urrestarazu et al. (2013)	Yes	No	No	Level of EC and NaCl
Thymus vulgaris	Cordovilla et al. (2013)	Yes	Yes	No	Level of EC and NaCl
Lavandula angustifolia	Cordovilla et al. (2013)	Yes	Yes	No	Level of EC and NaCl

Materials and methods

A 60-day-old parsley (*Petroselinum crispum* Mill.) plant (from seed) was potted in a 1 L pot. Each pot was filled with a mixture of coconut fiber and commercial peat moss (2:1; vol:vol). The experiment was conducted in a plastic greenhouse at Mohamed Premier University (Nador, Morocco) for 90 days. Four different treatments were established on 1 April. The control treatment (T1) consisted of a standard nutrient solution with an EC of 1.2 dS m^{-1}, which was similar to the nutrient solution described by Sonneveld and Straver (1994) for pot cultivation. Treatments T2 and T3 had incremental micronutrient concentrations with an electrical conductivity (EC) of up to 2.2 and 3.2 dS m^{-1}, respectively, using a concentration nutrient solution on base of macronutrients. Treatment T4 was the same as treatment T2, but was adjusted with NaCl to have an EC of up to 2.3 dS m^{-1}.s

Ninety days after transplanting, the plants were gently removed from their substrate. Next, the roots were washed with distilled water and the plant roots and shoots were divided for each treatment and replicate. Each sample was placed in a forced-air oven at 85°C until a constant weight was achieved. The weight was recorded with a scale that had a precision of 0.01 g.

The essential oil (EO) concentration was determined by hydro distillation of the aerial part (shoot) of the air-dried plants (500 g) with a modified Clevenger apparatus after 4 hours. These measurements began when the first drop of liquid condensed in the cooling column and dripped into the grade burette. EO production was calculated by adding the volume/weight ratio (vol/w) of the cold oil collected that was collected from the burette to the original material.

The experiment was completely randomized with 16 replicate and treatment pots (8 pots for growth and 8 pots for EO). A Tukey's multiple range test at $P \leq 0.05$ was used to differentiate the means. The experimental design and data analysis were based on the procedure described by Little and Hills (1987). The Statgraphics® Plus 5.0 statistical package was used to process the data (Statistical Graphics Corp., Rockville, MD, USA).

Results and discussion

The saline treatments negatively affected vegetative growth (at $P \leq 0.05$, Figure 1). Specifically, the growth was reduced by 30 and 40% for the dry and fresh weights of the shoots, respectively. Even for relatively moderate EC values (2.2 dS m^{-1}), which could be considered to be optimal for some aromatic plants such as Freisia (Sonneveld and Straver, 1994), plant production was reduced. This significant biomass reduction is important because a large portion of parsley plant production is marketed worldwide for seasoning fresh meals. These data are consistent with previously observed peppermint and lemon verbena biomass reductions with varying EC from 1.4 to 2.8 dS m^{-1} (Tabatabaie and Nazari, 2007) and with the results obtained by Urrestarazu et al. (2013) for lime thyme leafs. The effects of specific salt toxicity on the roots were not clear. The saline treatments with macronutrient concentrations (T2 and T3) had lower root growth (up to 50%); however, treatment T4 had the same root biomass as treatment T2. Because the roots are not commercialized and contain only small amounts of EO (approximately 0.1%) (Tyler et al., 1988), their biomass is less important from a commercial standpoint. The response of the parsley to the treatment suggested that it is highly sensitive to salinity (Figure 2).

When comparing the biomass weight of the plants grown in the nutrient solution with those grown in the concentrated macronutrient solution (T3) and NaCl (T4), a reduction in root and shoot growth was observed. Tabatabaid and Nazari (2007) observed the same effect for peppermint plants, and Urrestarazu et al. (2013) observed the same effect for lime thyme plants. Tabatabaid and Nazari (2007) observed that NaCl affected lemon verbena by significantly reducing its biomass when the EC increased due to the addition of NaCl but not macronutrients. This specific saline effect due to NaCl is well described by Sonneveld (2004) and Sonneveld and Voogt (2009).

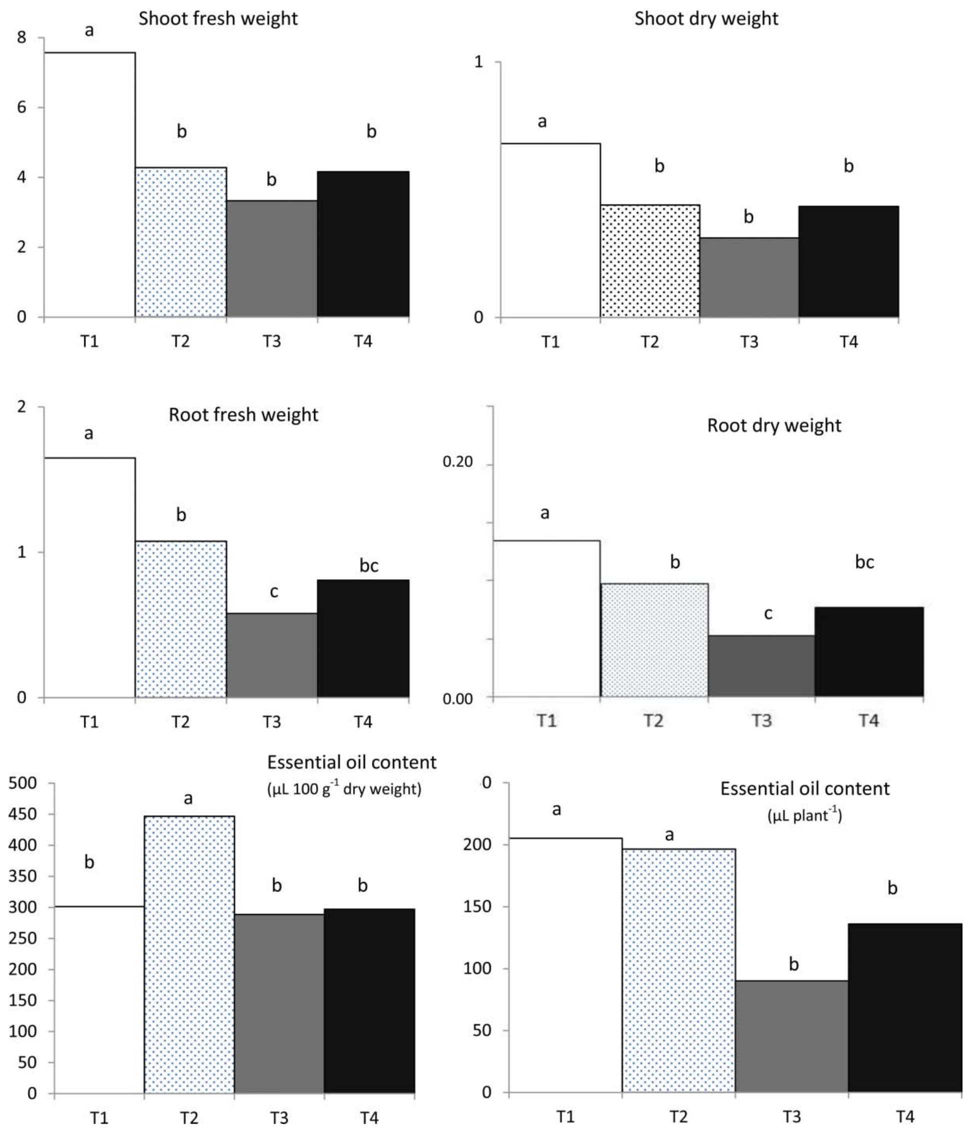

Figure 1. Growth parameter (g plant^{-1}) and essential oil contents of parsley. T1, T2, T3 and T4 indicate nutrient solution treatments with electric conductivities of 1.2, 2.2, 3.2 from concentrated nutrient solution on base of macronutrients, and 3.2 (with 6 mM NaCl), respectively. Different letters indicate significant differences ($P \leq 0.05$).

The EO concentrations that were obtained for the parsley shoot were similar to those reported by Tyler et al. (1998) and Orav et al. (2003).

The highest oil concentrations were obtained at moderate salinity values (EC = 2.2 dS m^{-1}, T2). No significant differences between the low (1.2 dS m^{-1}) and high (3.2 dS m^{-1}, T3 and T4) conductivity treatments were observed. However, because the greatest biomass was registered for treatment T1, it was concluded that the optimal EO production by the plants occurs at an EC of between 1.2 and 2.2 dS m^{-1}. Similar results were previously reported for peppermint, lemon verbena (Tabatabaie and Nazari, 2007) and lavender (Maia et al., 1999). Therefore, under very controlled conditions (as in soilless cultures) and when the tolerance and response of a plant to specific salinity levels are known, fertigation (composition of the nutrient solution) can be controlled. Depending on their aim, produces can 1) improve biomass development, 2) improve EO productivity or 3) optimize these first two factors.

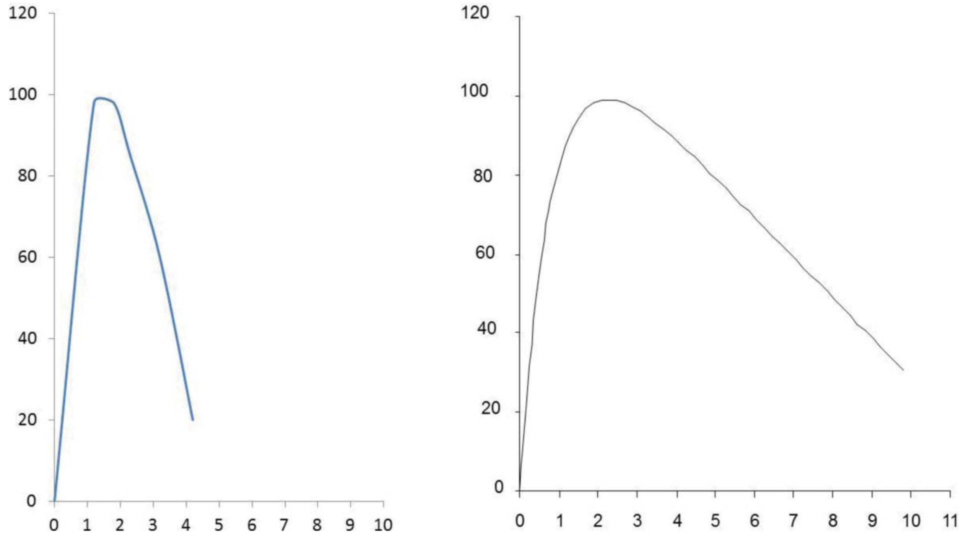

Figure 2. Comparative mean yield (%) of parsley and chrysanthemum with the nutrient solution EC (dS m^{-1}) [Sonneveld (2004) and Sonneveld et al. (2005)].

Conclusions

The results suggest that an EC of 1.2 dS m^{-1} is optimal for obtaining high economic yields, particularly for biomass yields (which have basic several uses). However, moderate EC values between 1.2 and 2.2 are beneficial for parsley crop essential oil production in soilless cultivation.

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